

# The Effects of Boiling and Leaching on the Content of Potassium and Other Minerals in Potatoes

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**ABSTRACT:** The white potato (*Solanum tuberosum* L.) is a valuable source of potassium in the human diet. While most consumers benefit from high levels of potassium in potato tubers, individuals with compromised kidney function must minimize their potassium intake. This study was undertaken to determine the effects of leaching and boiling on levels of potassium and other minerals in potato tubers. Leaching alone did not significantly reduce levels of potassium or other minerals in tubers. Boiling tuber cubes and shredded tubers decreased potassium levels by 50% and 75%, respectively. Reductions in mineral amounts following boiling were observed for phosphorus, magnesium, sulfur, zinc, manganese, and iron. There was no difference between the leaching and boiling treatment and the boiling treatment. In addition, mineral levels in tubers of 6 North American potato cultivars are reported. Significant differences in mineral levels were detected among cultivars, but they were too small to be nutritionally important. Individuals wishing to maximize the mineral nutrition benefits of consuming potatoes should boil them whole or bake, roast, or microwave them. Those who must reduce potassium uptake should boil small pieces before consuming them.

**Keywords:** boiling, leaching, minerals, potassium, potato

## Introduction

Minerals are an important part of a healthy diet. Nutrition professionals recommend that they be consumed as part of a balanced diet, primarily as fruits and vegetables, rather than in the form of dietary supplements. The recommended daily allowance in adults for potassium (K) is 4000 to 4700 mg, and this is much higher than for other minerals such as calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn), where the recommended amounts are 1000 to 1600, 310 to 500, 18 to 21, and 8 to 14 mg/d, respectively (Anonymous 2005). Potassium is required in relatively large amounts because it functions as an important electrolyte in the nervous system. Potassium is used to regulate heartbeat, conduct nerve impulses, and contract muscles. Potassium also plays a role in osmoregulation. High levels of potassium can help to control high blood pressure (Adroque and Madias 2007) and may decrease the risk of stroke (Ascherio and others 1998; Ding and Mozaffarian 2006). Despite its importance for good health, many Americans, especially individuals with hypertension, do not get sufficient K in their diet (Anonymous 2005).

A significant portion of the K consumed each day is excreted through normal kidney function. This prevents K from accumulating to toxic concentrations, but necessitates constant replenishment of K through diet. The complications from elevated K include weakness, numbness, and tingling, and in more severe cases, irregular heartbeat or heart attack (Beto 1995; Beto and Bansal 2004). Elevated K is of special concern for patients with chronic kidney disease. In 1 study of kidney failure patients, elevated K from the diet was found to increase the chance of nerve damage in legs

and feet (Krishnan and others 2006). Patients with kidney disease are advised to moderate their intake of K through careful selection of foods and by preparing foods in ways that minimize K consumption.

The white potato (*Solanum tuberosum* L.) is an important source of dietary K (Kolasa 1993). In North America and many parts of the world, potatoes are consumed more than any other vegetable. Annual consumption of potatoes in the United States is approximately 61 kg per person (<http://www.ers.usda.gov/Data/FoodConsumption>). In parts of South America, potato is a staple crop and consumption can be as high as 800 g per person each day (Burgos and others 2007). As a percentage of fresh weight, the K content of potato tubers is relatively high (approximately 0.49%) and compares favorably with other sources of K. Consumption of potatoes may benefit healthy persons by adding K and other minerals to their diet, but potato consumption by persons with chronic renal failure may be harmful. The recommended potassium intake in kidney dialysis patients is 2 to 4 g/d (Beto 1995). For these persons, leaching cut potatoes in water prior to cooking is advised as a way to reduce K content (Tsaltas 1969; Cost 1975; Gillit and others 1987). The recommended procedures for leaching vary, however, and little information on the effectiveness of leaching is available.

The method used to prepare food influences its nutritional content in general and the content of K and other minerals in particular. Boiling is a common method used to prepare potatoes, and boiling reduces the K content of peeled whole potatoes by 16% compared to baked potatoes (Anonymous 2005). Data describing how well K and other minerals are retained in potatoes cut to various sizes before leaching and boiling are lacking. In this study, we present a comprehensive examination of the effect of leaching and boiling on the mineral content of potatoes. These data will provide guidance to nutritionists developing diets that contain appropriate amounts of K and other minerals, and to clinicians who advise

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patients with compromised renal function on ways to reduce K consumption.

## Materials and Methods

Two trials were carried out with potato tubers produced using conventional cultural practices at the Univ. of Wisconsin-Lelah Starks Potato Research Station near Rhinelander, Wis., U.S.A. They were harvested in September 2006 and stored at 2.2 °C until the spring of 2007, when they were used for this study.

In the 1st trial, tubers of each of 6 cultivars ("Russet Norkotah," "Ranger Russet," "Red Norland," "Yukon Gold," "Superior," and "Kennebec") were washed, peeled, and diced into 1-cm cubes. The cubes were divided into 30-g samples. Three samples (replications) were prepared for each treatment. The leaching treatment consisted of soaking each sample in 300 mL distilled water at 5.6 °C for 20 h. Distilled water was used to eliminate the possibility that tuber pieces would accumulate minerals from the water. Twenty hours, which is the length of time from 10 PM to 6 PM the next day, was selected as the longest time that individuals are likely to leach potato pieces. It was assumed that leaching would take place in a refrigerator at 5.6 °C to minimize microbial growth. The water was then decanted off and the sample was lyophilized prior to mineral analysis. The leaching and boiling treatment consisted of leaching, decanting the water off and replacing it with 300 mL fresh distilled water, bringing the water to a boil, boiling for 10 min, decanting the water off, and then lyophilizing the sample. The control consisted of lyophilized raw tuber samples. One freeze-dried sample of each replication of each treatment was ground into a powder using a mortar and pestle. For each sample, 500 mg of dried tuber tissue and 5 mL of concentrated nitric acid were added to a 50-mL Folin digestion tube. The mixture was heated to 120 to 130 °C for 14 to 16 h and then treated with hydrogen peroxide. After digestion, the sample was diluted to 50 mL. This solution was analyzed for minerals by inductively coupled plasma optical emission spectrometry.

The 2nd trial was identical to the 1st trial, except that only cultivars "Russet Norkotah," "Red Norland," and "Superior" were included. An additional tuber treatment was added. Shredded tubers (2 × 5 mm × tuber length) were evaluated along with cubes. An additional processing treatment, boiling, was also added. The boiling treatment consisted of placing a freshly prepared sample in 300 mL distilled water, bringing the water to a boil, and then boiling for 10 min. The water was then decanted off and the sample was lyophilized.

Statistical analyses included analysis of variance (ANOVA) using the general linear model in SAS and means separation using a protected least significant difference test at  $P = 0.05$ .

## Results

### Variation in mineral content among potato cultivars

Figure 1 and 2 present mineral levels in the 6 cultivars evaluated in the 1st trial. Potassium was the most abundant mineral, as expected, and varied from an average of 1.98% of dry weight in "Ranger Russet" to 2.31% of dry weight in "Superior" (Figure 1). "Red Norland" and "Superior" were significantly higher in K than "Russet Norkotah," "Ranger Russet," and "Yukon Gold" ( $P = 0.05$ ). Values of K near 2% of dry weight agree with the value of 0.49% K in whole (skin and flesh), raw potatoes used for the USDA food label, given that typical dry weights are 15% to 20% of fresh weight. They also agree with other published studies on potato tuber nutrient levels (True and others 1978; Klein and Mondy 1981; Randhawa and others 1984). Other minerals present in the potato samples at moderate (P, Ca, Mg, S) or low amounts (Zn, B, Mn, Fe, Cu) exhibited

differences among cultivars as well (Figure 2A and 2B), and these differences were often statistically significant at  $P = 0.05$ .

### The effect of leaching and boiling on K content

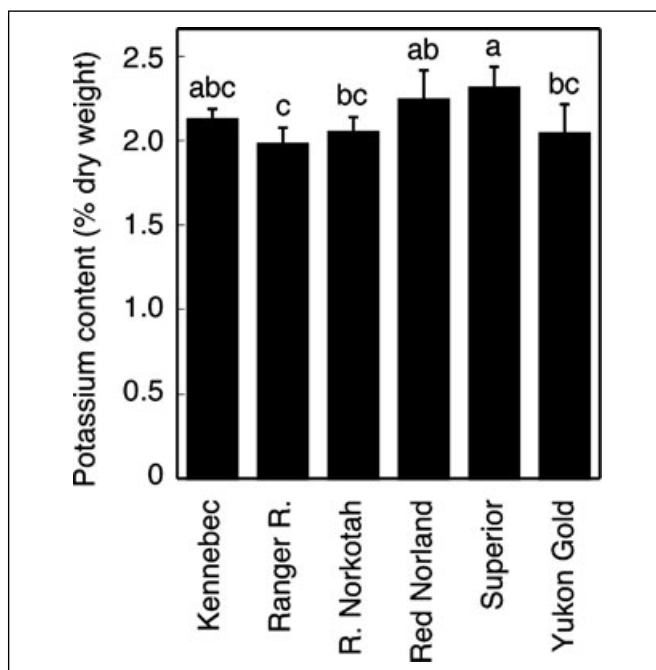
Leaching and boiling of potato pieces are 2 treatments that are the most likely to have an impact on mineral content of the consumed product. We analyzed mineral content of potatoes cut into cubes (trial 1 and 2) or shredded into strips (trial 2). We also determined the mineral content of these samples after leaching overnight in cold water (trial 1 and 2), after boiling until tender (trial 2), and after both leaching and boiling (trial 1 and 2). The data from these treatments in trial 2 are presented in Figure 3 to 5. Trial 1 produced similar results.

The amount of K remaining in the potato samples was strongly dependent on the preparation method. Leaching of cubed samples had little effect on K content, and the average amount of K remaining was 96% and 100% of control values in trials 1 and 2 (Figure 3), respectively. Shredded samples retained less of their K after leaching, but K amounts after overnight leaching were still 83% to 98% of control values (Figure 3).

Boiling samples immediately after cubing or shredding resulted in a much greater loss of K. Boiling cubed potato pieces reduced the amount of K remaining in the samples to 50% of control values (Figure 3). Boiling shredded samples resulted in an even larger loss of K. Total K content in the shredded and boiled samples was only 25% to 31% of that in control samples (Figure 3). Boiling after overnight leaching did not result in a greater loss of K compared to boiling alone (Figure 3), except for shredded samples from "Red Norland," where K content was reduced to 31% of controls in boiled samples and 24% in samples leached overnight and then boiled, although these values were not statistically different at the level of  $P = 0.05$ .

### The effect of leaching and boiling on minerals other than K

Several other minerals are found in potato tubers, and their relative amounts after leaching and boiling followed the same general



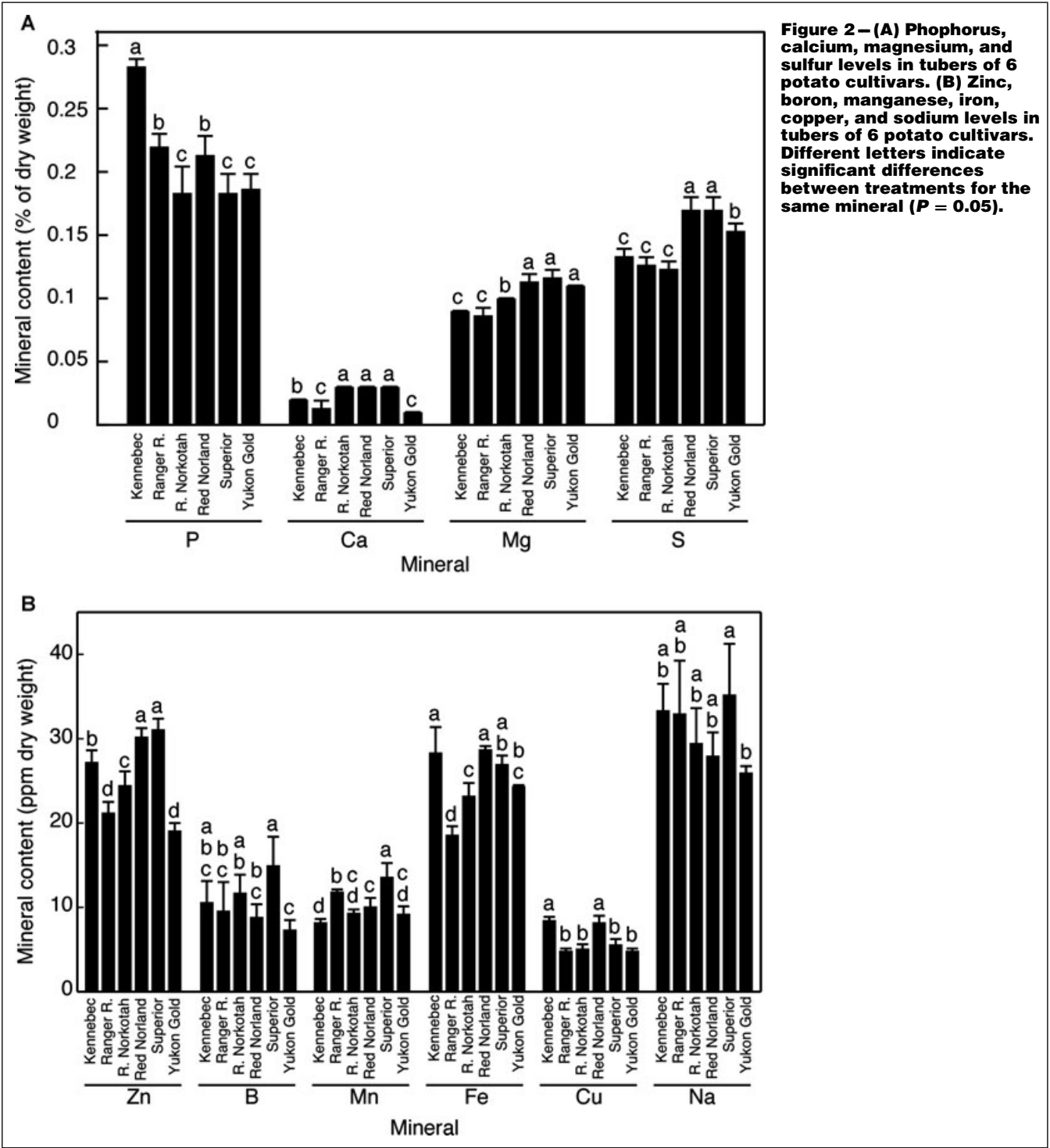
**Figure 1 — Potassium content in tubers of 6 potato cultivars. Different letters indicate significant differences between treatments ( $P = 0.05$ ).**

trend as K with respect to their retention (Figure 4 and 5). For each of the 3 cultivars common to both trials, P, Mg, S, Zn, Mn, and Fe levels were significantly reduced following the leaching plus boiling or boiling alone treatments. Calcium, B, and Cu levels did not always follow this trend. Levels of Mg, S, Mn, and Zn were all reduced by an average of 50% or more in the shredding and boiling treatment. Of these, the largest percentage loss was observed for Mg. Only 30% of the control Mg content was found in shredded and boiled samples (Figure 4). Cubed and boiled samples lost 35% of their total Mg. Zn and Mn are present in low amounts, but both showed significant, large losses of approximately 50% on average

following shredding and boiling, and 25% to 30% following cubing and boiling (Figure 5). The exception was for “Superior,” where a 65% reduction in Mn content was observed with the shred, leach, and boil treatment, but only a slight reduction in Mn content with the shred and boil treatment (Figure 5).

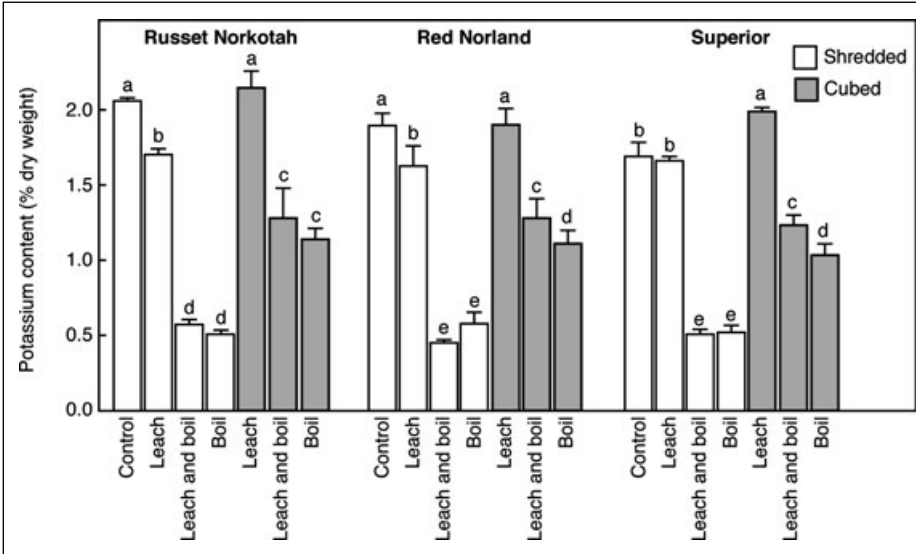
Discussion

The data presented here support 3 important findings with regard to the effects of processing on mineral content of potato tubers. First, the content of K and other minerals was drastically reduced by either cubing or shredding potatoes and then boiling

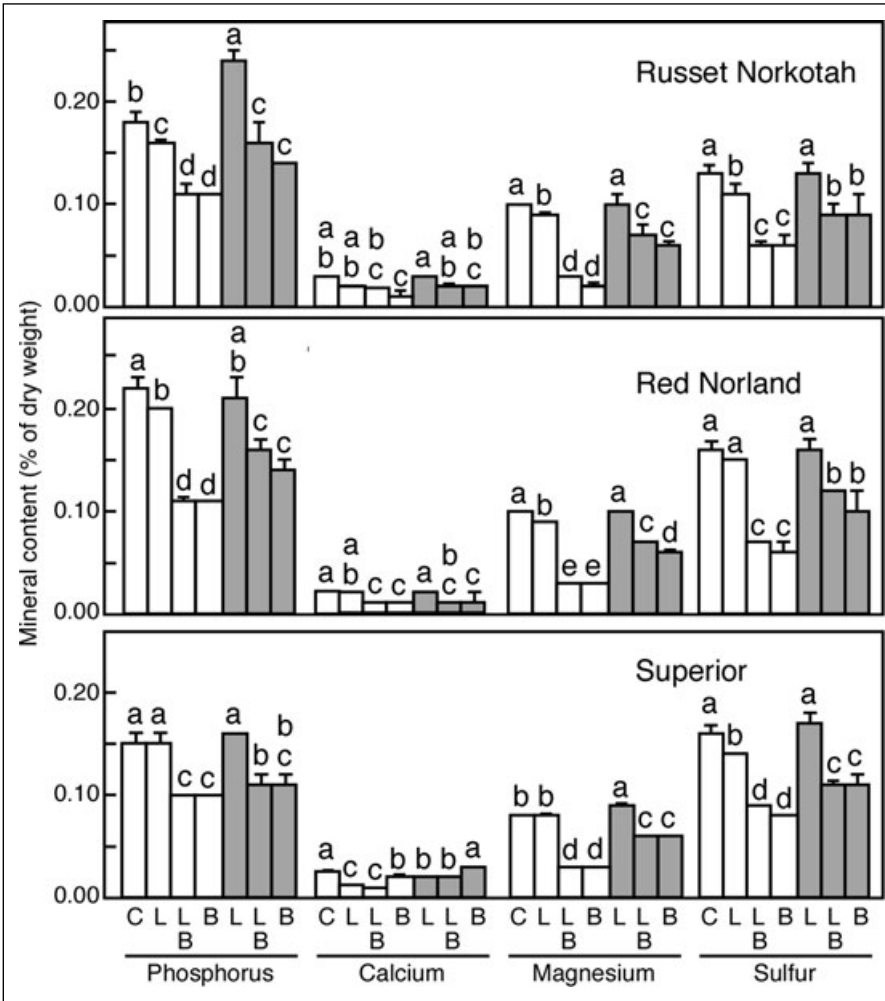


them (Figure 3 to 5). Reductions in K were as large as 75% of controls for samples that were shredded prior to boiling and 45% of controls for samples that were cubed prior to boiling. These values are much greater than published values for the K content loss that results from boiling whole, peeled potatoes (True and others 1979). This is also in contrast to the negligible loss of Fe and Zn when whole, unpeeled potatoes are boiled (Burgos and others

2007). For individuals wishing to maximize mineral consumption through diet, these data suggest that boiled potatoes should not be cut into small pieces as is commonly done to reduce cooking time. Second, leaching samples overnight had a much smaller effect on the mineral content of potatoes than boiling. Because leaching alone was an ineffective method for reducing the K content of potatoes, there would be little gain for renal failure patients trying



**Figure 3—Potassium content remaining in tubers of 3 potato cultivars following cubing or shredding prior to leaching and/or boiling treatments. Different letters indicate significant differences between treatments ( $P = 0.05$ ).**



**Figure 4—Effects of leaching and boiling treatments of shredded and cubed potatoes on phosphorus, calcium, magnesium, and sulfur levels in 3 potato cultivars. Different letters indicate significant differences between treatments for the same mineral ( $P = 0.05$ ). Clear bars = shredded samples, grey bars = cubed samples, C = control, L = leached, LB = leached and boiled, B = boiled.**

to reduce K consumption to prepare hash browns, for example, from shredded and leached potatoes than from freshly shredded potatoes.

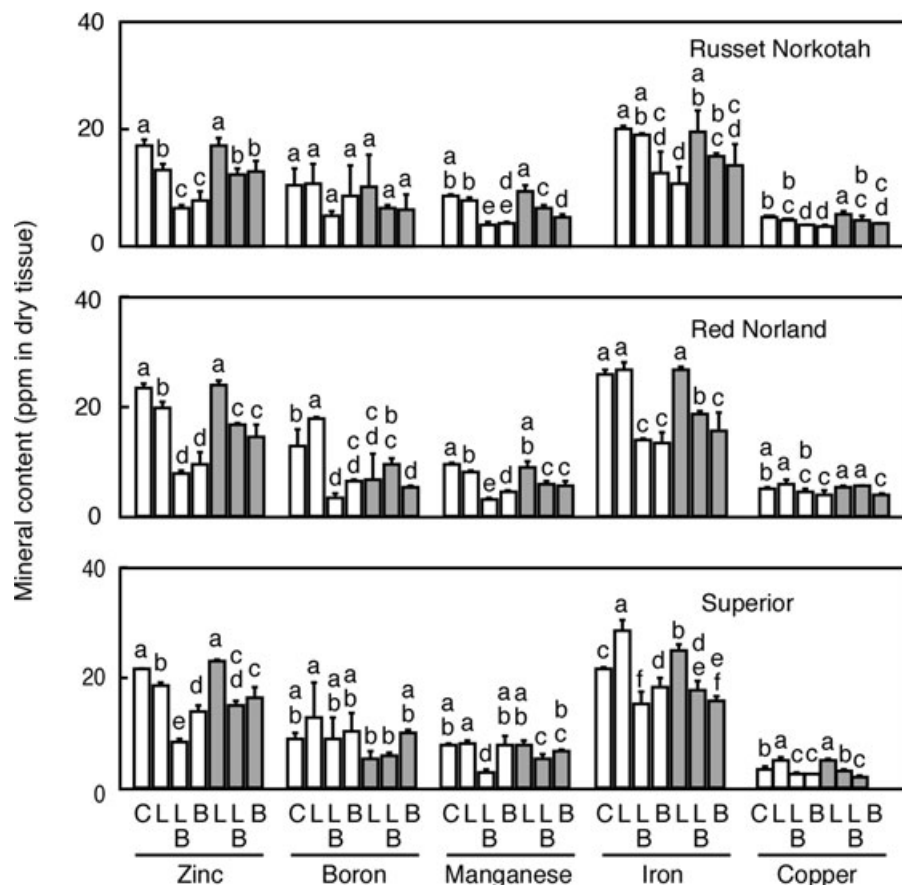
Finally, the data presented here show that mineral loss following boiling alone was comparable to that following leaching overnight and then boiling. These data suggest that the greatest benefits for individuals attempting to minimize the K consumed in boiled potatoes come from cutting potatoes into small pieces or shredding them, with very little additional benefit from leaching them after cutting. These 3 findings provide additional guidance to health professionals and consumers who are making diet choices based, in part, on the mineral content of the food.

The original “dialysis of the vegetables *in vitro*” method for reducing the K content of potatoes and other vegetables was put forward by Tsaltas in 1969 and has been recommended for patients with kidney disease ever since. Reductions in K content were found to be much greater when diced or sliced potatoes were leached prior to boiling. In particular, K reductions for thinly sliced potatoes after boiling for 5 to 10 min were approximately 50%, and reductions with leaching and boiling were approximately 80% (Tsaltas 1969). No details were provided as to potato variety, and the data do not include measures of variability from the mean. The data presented here support the findings of Tsaltas (1969) showing that boiling thinly sliced potatoes resulted in greater K loss than boiling diced potatoes (Tsaltas 1969). They differ from previous findings (Tsaltas 1969) in that they do not show a significant, additional benefit from leaching (Figure 3). For each of the 3 varieties tested, as well as for diced and shredded potatoes, boiling alone was as effective as leaching and boiling as determined by us (Figure 3) or others (Tsaltas 1969). We conclude that the time-consuming

and inconvenient leaching step is unnecessary and can be omitted.

This study also analyzed the mineral content of tubers from 6 major potato cultivars. We chose major cultivars that represent the common market classes of potato. “Ranger Russet” and “Russet Norkotah” are russet cultivars, “Superior” and “Kennebec” are white potatoes, “Red Norland” is a red-skinned cultivar, and “Yukon Gold” is a popular yellow-fleshed potato. All are typically eaten as fresh market potatoes, although “Ranger Russet” and “Superior” are processed as well. Significant differences in mineral content among cultivars were detected in this study and a previous one (True and others 1979). However, these differences were typically small and would not justify the choice of one cultivar over another for its nutritional quality with respect to mineral content. For example, the amount of K in the cultivar with the lowest level (“Ranger Russet”) was 85% of that of the highest cultivar (“Superior”). Assuming that dry weight is 20% of fresh weight, the K content in a 250-g “Ranger Russet” tuber would be 1.1 g, while that in a comparable “Superior” tuber would be 1.0 g. Our study showed that cooking has a much more dramatic effect on mineral levels, with shredded tubers from boiling treatments containing only 25% of the K found in raw tubers.

The genetic variability among North American cultivars is low (Mendoza and Haynes 1974), so it is not surprising that the cultivars evaluated in this trial are similar in mineral content. In contrast, mineral content varied more widely in Andean potato cultivars, which are more genetically diverse (Burgos and others 2007). For example, the Andean cultivar with the lowest Fe levels was 44% of that of the highest cultivar. In our trial, the lowest cultivar was 64% of the highest cultivar. Potato breeders are fortunate to have



**Figure 5 – Effects of leaching and boiling treatments of shredded and cubed potatoes on zinc, boron, manganese, iron, and copper levels in 3 potato cultivars. Different letters indicate significant differences between treatments for the same mineral ( $P = 0.05$ ). Clear bars = shredded samples, gray bars = cubed samples, C = control, L = leached, LB = leached and boiled, B = boiled.**

access to about 200 wild relatives of potato. Wild species provide genes for resistance to biotic and abiotic stresses, as well as tuber quality (Hanneman 1989; Spooner and Bamberg 1994; Jansky 2000). In 1 study, tuber calcium levels in wild *Solanum* species were reported to range from 0.016% to 0.074% dry weight, compared to a range of 0.010% to 0.030% in the cultivars evaluated in our trial (Bamberg and others 1993). Based on previous successes with the introduction of valuable genetic diversity from wild potato species into cultivated germ plasm, breeding efforts could likely increase tuber mineral content to levels higher than are currently found in potato cultivars. Consequently, in the future, it may be possible for consumers to select cultivars based in part on nutritional value.

### Conclusions

In conclusion, tuber mineral levels can be easily manipulated to meet the needs of consumers. If the goal is to add minerals to the diet through the consumption of potatoes, then this can be done by boiling whole potatoes or potatoes that have been cut into large pieces. Alternatively, potato tubers can be microwaved, baked, or roasted without a loss of mineral nutrients (True and others 1979). As such, potatoes are a valuable source of potassium and other mineral nutrients. If it is necessary to decrease mineral uptake while taking advantage of other nutritional qualities offered by potato tubers, as is the case with individuals who have compromised kidney function, then boiling thinly sliced potatoes will result in a large reduction in mineral levels. Furthermore, the data presented here show that it is not necessary to complicate the process by leaching tuber slices before boiling them.

### Acknowledgments

The authors wish to acknowledge Krista Powell, R.D., L.D., who stimulated the initiation of this study.

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